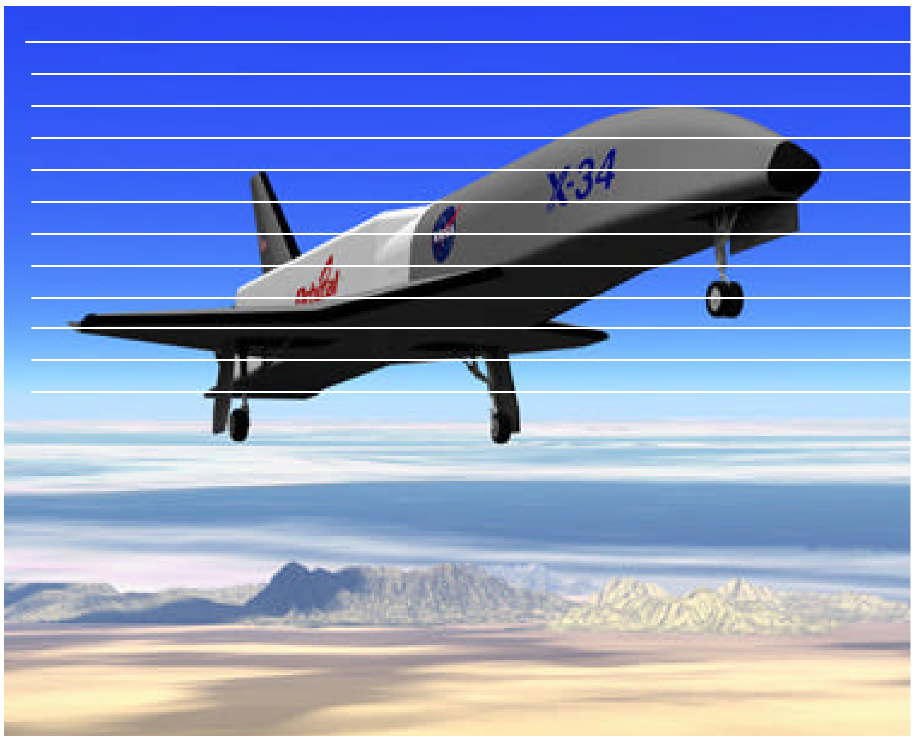
X[34]

Safety & Mission Assurance Review



NASA

Office of Safety & Mission Assurance

June 17, 1998

Executive Summary

Background:

The X-34 Program safety and mission assurance (SMA) management processes were reviewed by the NASA headquarters Office of Safety and Mission Assurance (OSMA) during May 1998. The review process included advance discussions over a three week period involving the core NASA review team and Orbital Sciences SMA process owners. A formal on-site review was held on May 22, 1998.

NASA is the sponsor and a risk-sharing partner in the X-34 program. The review fulfills, in-part, the government management responsibilities to assure public safety, exercise care in management of financial resources, and promote the likelihood of achieving mission success. The X-34 is one of NASA's Better/Faster/Cheaper initiatives. It is a technology testbed, hypersonic vehicle, air launched from an L-1011 carrier aircraft. The X-34 will operate up to 85,000 feet at Mach 2.6, in the baseline program, and up to 250,000 feet at Mach 8 in the optional flight test program. The three-year baseline program has been implemented using a firm fixed price contract with an initial value of approximately $60 million. The program is managed by the NASA Marshall Space Flight Center and conducted by Orbital Sciences Corporation (OSC) in Dulles, Virginia.

The NASA safety and mission assurance role is evolving. Traditional oversight included extensive documentation, government specifications, government inspections, and formal approval on many programmatic design decisions. This directive approach is being replaced with the new role of "informed observer and risk management consultant." This report is intended to document the "process level insight" acquired as a result of the review and to assist in defining the continued level of SMA insight necessary for NASA to assume additional liability for mishaps which may occur in X-programs, as currently proposed in legislation before Congress.

Findings:

The review team found that key SMA processes are in place, and are being implemented in a successful fashion. The team observed that the X-34 is innovative in many ways, "an experiment in management as well as technology," as noted by the OSC program manager Dr. Robert Lindberg. The program is very lean (less that 60 people), with three full-time dedicated SMA staff. Many SMA functions are managed through OSC corporate-matrix support and task agreements with government entities (NASA Army, Air Force). This unique approach has the potential for increasing vulnerability. The NASA MSFC X-34 program and MSFC SMA must focus insight efforts to assure follow-through in implementation of the SMA processes and to assure that proper staffing levels and skill mixes are maintained, especially if the program implements the optional flight test program.

It was noted that tailored range safety activity, flight termination system design and approval, L-1011 certification, and communication security issues have been identified and are being addressed. At a process level, the right organizations are addressing the right issues. Ultimate risk management decisions will be made by X-34 program management and the appropriate test range officials. The review team observed that the NASA MSFC SMA insight role is unnecessarily complicated by an inherent conflict of interest resulting from the assignment of a single individual to simultaneously assume three oversight/insight roles: sub-contractor to OSC on the Main Propulsion System development; insight-consultant to the NASA X-34 program manager (over OSC), and oversight to the MSFC FASTRAC engine program. The report recommends that this situation be remedied to assure a smoother and more effective implementation of insight responsibilities. The review team also recommended that MSFC SMA consider amending their Annual Operating Agreement (AOA) to identify the required resources necessary to effectively carry out their oversight/insight roles related to the X-vehicle programs. It was also observed that the integration of the NASA-furnished FASTRAC engine with the X-34 airframe posed some management challenges for both OSC and NASA program managers. Concerns were raised that SMA interfaces were not clearly understood and that increased communication and cooperation among parties was essential to ultimate success.

It was further noted that the baseline flight test program to be conducted at White Sands Missile Range (WSMR) posed a minimum risk to public safety as all operations will be confined to the range. Expansion of the program to the optional flight test program (OFTP) will necessarily take place somewhere other than WSMR, either the California/Nevada/Montana corridor or the Eastern Range (from Wallops Island, Virginia to Kennedy Space Center, Florida). Prior to moving to the OFTP, it is recommended that another NASA top-level SMA review be conducted to examine range safety issues, flight termination system (FTS) issues, public safety hazards (east coast abort), and the required increases in OSC SMA staffing necessary to accommodate more complex operational requirements. The review team also noted that the current X-34 flight test approach calls for an abrupt expansion of the performance envelope from Mach 2.6 to Mach 8. This approach poses increased risk as compared with a more incremental approach. This programmatic risk management decision must be taken carefully, considering the potential increase in population at risk in operating off of WSMR and the inherent risk associated with greatly expanding the performance demand on the vehicle.

Conclusion:

The SMA process-level view is positive. The NASA/Orbital Sciences X-34 Better/Faster/Cheaper program is on the right path. However, vigilance (by all parties) is necessary to assure the continued success of the program. Ongoing insight must assure that fundamentally sound SMA processes are being implemented throughout the program life-cycle.

Table of Contents

1.0 Introduction

A review of the X-34 safety and mission assurance (SMA) processes was conducted on May 22, 1998, by the NASA Associate Administrator for Safety and Mission Assurance in coordination with the Deputy Associate Administrator for Aeronautics and Space Transportation Technology. The purpose of this review was to establish a better understanding of the X-34 risk management approach and SMA processes which are being implemented to assure safety of flight and mission success.

NASA is ultimately accountable and liable to Congress and the American people for the safe and successful conduct of all NASA programs. There is a shared responsibility between NASA and its industry contractors to assure that programs are conducted safely and successfully.

Safety and Mission Assurance (SMA) "insight" is required if NASA is to fulfill management responsibilities. As currently structured NASA is a risk sharing partner in the X-34 program. However, NASA will assume additional liability and risk if pending "Third Party Liability" waiver legislation is approved. This proposed legislation requires "developer to establish to the satisfaction of the NASA Administrator that appropriate safety procedures and practices are being followed."

The objectives of the X-34 SMA review were to:

- attain <u>process level insight</u> into the X-34 Program
- understand the SMA and Risk Management processes employed by Orbital Sciences Corporation in the X-34 vehicle design, manufacture, and operation
- understand the SMA processes employed by NASA/MSFC in the development of the FASTRAC engine
- understand SMA issues related to the X-34 program

The review, chaired by Frederick D. Gregory, Associate Administrator for Safety and Mission Assurance, included staff from the Headquarters Office of Safety and Mission Assurance, the Marshall Space Flight Center (MSFC) Office of Safety and Mission Assurance, the NASA X-34 Program Office, the NASA FASTRAC Engine Program Office, the U.S. Army White Sands Missile Range (WSMR), the Kennedy Space Center X-34 Program Office, and the U.S. Air Force, 45th Space Wing at Cape Canaveral Air Force Station. Observers included the NASA Headquarters Inspector General and members of the Aerospace Safety Advisory Panel (ASAP).

2.0 Background

2.1 X-34 Program Objectives

The intent of the X-34 program is to demonstrate "key technologies" applicable to future Reusable Launch Vehicle (RLV) systems. The X-34 was conceived as a bridge between the Clipper Graham (DC-XA) and the X-33. The X-34 contract is managed by the Marshall Space Flight Center. (MSFC).

OSC is responsible for providing two X-34 vehicles that have the capability of completing 25 test flights within a one year period. These test flights are intended to demonstrate: 1) autonomous flight operations, including return and landing at a designated site, 2) vehicle safe abort which involve engine out, propellant dump, and landing, 3) operations in expected RLV-type environments and conditions including landings in cross winds up to 20 knots, subsonic flight through rain and fog, powered flight to at least 250,000 ft., and attaining flight mach numbers of 8 or greater, and 4) embedded or on-board RLV technologies in addition to providing the ability to accommodate other RLV technologies.

<u>X-34 Technology Demonstration Objectives</u>

- Integration of new technologies
- 25 test flights over a period of one year
- Autonomous flight operations
- Safe abort capability
- Technology demonstration throughout flight profile
- Subsonic and hypersonic flight
- Powered flight to at least 250 kft
- Speeds of Mach 8
- Advanced RLV technology demonstration
- Composite structures (aero, prime airframe, and thrust structures)
- Composite propellant tanks and cryo insulation
- Advanced operable TPS including leading edge materials
- Advanced low cost avionics (GPS/INS)
- Rapid low cost flight software development tools
- Integrated vehicle health monitoring
- Ability to attain average recurring flight cost
- Adaptable as a low Mach number test bed (embedded, attached, or deployed), e.g., Rocket-Based Combined Cycle; Plug Nozzle; Pulse detonation wave; dual bell expansion engines

<u>X-34 Key Technologies</u>

- Composite Primary and Secondary Airframe Structures

- Composite airframe including primary structure, aerosurfaces, and thrust structures.
- High-margin structure designed to require minimal inspection, with modular design and numerous access ports for maintainability
- Composite reusable propellant tanks, cryogenic insulation, and propulsion system elements
- Advanced thermal protection systems and materials
- Low-cost, low-weight thermal protection systems and materials on the leading edges and other critical heating areas
- Low-cost flight proven avionics including differential GPS and integrated GPS/INS.
- Integrated vehicle health monitoring system.
- Flush air data system
- Platform for demonstration of "added on" or additional experiments
- Low cost to manufacture engine (ie. FASTRAC)

2.2 X-34 Contract

In response to NASA Research Announcement (NRA) 8-14, the X-34 contract was competitively awarded to Orbital Sciences Corporation (OSC) on August 28, 1996. The initial contract specified a firm-fixed-price amount of $49,540,584, including Government Task Agreements in the amount of $9,631,433 for a period of performance through February 9, 1999. Including the latest Characterization and Validation (change of scope) modification, the current value of the contract and Government Task Agreements is $75,165,938 and $11,843,083, respectively, with a performance period through October 1999.

Under this contract, Orbital is responsible for the design, development, fabrication, integration and flight testing of the X-34 test bed demonstration vehicle including completion of post-flight activities, reports, and analyses associated with the two flights specified in the Basic Flight Test Program. The contract also contains a 25 flight Optional Flight Test Program to investigate operability issues and host key technology experiments relevant to X-33 and other reusable launch vehicles (RLV).

X-34 Risk Sharing Partnership

Issues of liability and indemnification are described in Section H.7 of the contract. This section, in part, states:

> "The parties recognize that potential liability to third parties is a concern against which OSC desires indemnification by NASA. If legislation is enacted which provides NASA specific authority, NASA agrees to process OSC's application to indemnify OSC against claims of third parties for death, bodily injury, or loss of damage to property resulting from flight testing of the X-34 vehicle in the performance of this contract. In the event that indemnification is not provided, either because legislation is not enacted or because an application for

> indemnification submitted by OSC is disapproved for good reasons, OSC shall be responsible, either through insurance or otherwise, for any third party liability it may incur under this contract. In this event, the parties rights and obligations will be governed by FAR 52-228-7, Insurance-Liability to Third Persons, with the proviso that the government shall not be responsible for more than 50% of the third party liability insurance premiums, at the time the policy goes into effect, and these costs are subject to the Contracting Officer's prior approval. At such time, an equitable adjustment will be made to the Contract to cover the Government's payment of the Government's share of the insurance premiums. OSC shall be responsible for insurance premiums above the Government's agreed payments. The insurance policy value shall be $500 Million maximum liability."

Under pending legislation (Senate Bill 1250), indemnification or partial indemnification would be granted for contractors conducting NASA X-program research and development activities. However, this legislation also states: "The Administrator may not provide liability insurance or indemnification unless the developer establishes to the satisfaction of the Administrator that appropriate safety procedures and practices are being followed in the development of the experimental aerospace vehicle." To meet this requirement, NASA, as the government risk-sharing partner, must possess adequate insight and understanding into the X-34 safety and mission assurance processes.

<u>X-34 Government and Industry Partners</u>

In addition to Orbital Sciences Corporation of Dulles, VA, the X-34 industry team includes:

- Allied-Signal Corporation, Tempe, Arizona, - responsible for the flight control actuators and hydraulic pump system;
- Oceaneering Thermal Systems, Houston, Texas - responsible for thermal protection blankets;
- C.S. Draper Laboratory, Cambridge, Massachusetts, - responsible for reentry and approach algorithm and software.

Government facilities involved on the X-34 program include:

- NASA Marshall Space Flight Center, Huntsville, Alabama, - responsible for program management, Main Propulsion System Design, FASTRAC engine;
- Langley Research Center, Hampton, Virginia, - responsible for wind tunnel testing and analysis;
- Ames Research Center, Mountain View, California, - responsible for rigid thermal protection system;
- Dryden Flight Research Center, Edwards AFB California, - responsible for certification testing
- Holloman AFB, New Mexico, - responsible for flight support operation

- White Sands Test Facility, New Mexico, responsible for flight support operation
- White Stands Missile Range, New Mexico, responsible for testing and flight support operation.

2.3 X-34 Vehicle Characteristics

The vehicle is being designed and developed by Orbital Sciences Corporation. It will be powered by a government-furnished engine. The main engine is a 60,000 pound thrust version of the FASTRAC LOX/kerosene engine being developed by the Marshall Space Flight Center. This is a simple engine which uses a gas generator cycle and a single turbopump based on the previously developed Marshall Simplex LOX pump.

The X-34 is considerably smaller and lighter than the X-33. It is capable of hypersonic flight to Mach 8, compared with the X-33's Mach 15. Consequently, it is considerably less expensive and simpler to develop, to operate, and to modify for flight experiments. It has different embedded technologies and a different operational concept. The flight testing will focus on RLV-type operations, the embedded technologies, and technology test articles to be carried as experiments.

Test-bed instrumentation will satisfy the needs for the embedded technologies demonstration, and for some additional experiments to be carried. Additional instrumentation requirements will be dictated by the demands of the experiments to be conducted. Figures 2.1 and 2.2 provide schematic and expanded views of the X-34 vehicle.

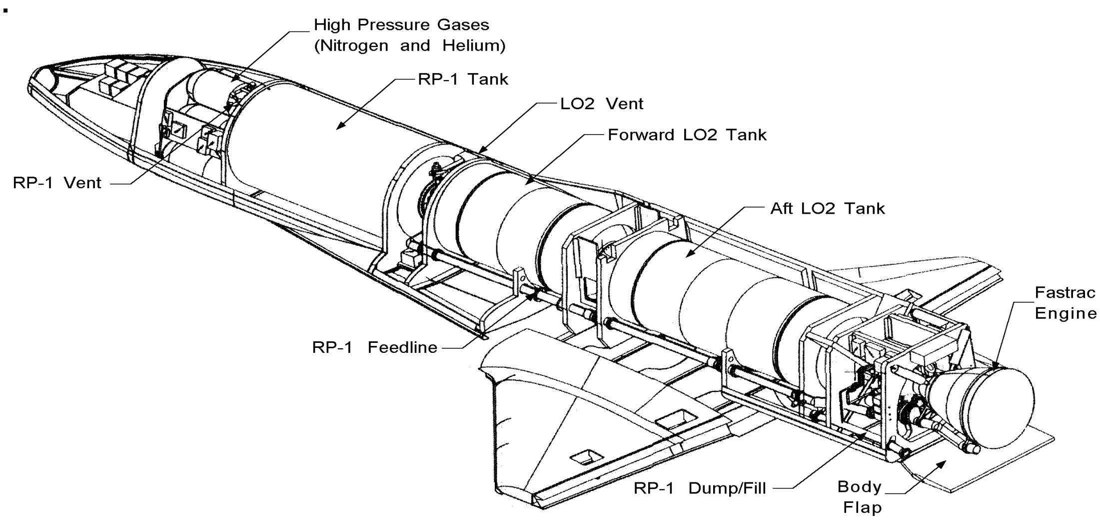


Figure 2.1: X-34 Schematic Drawing

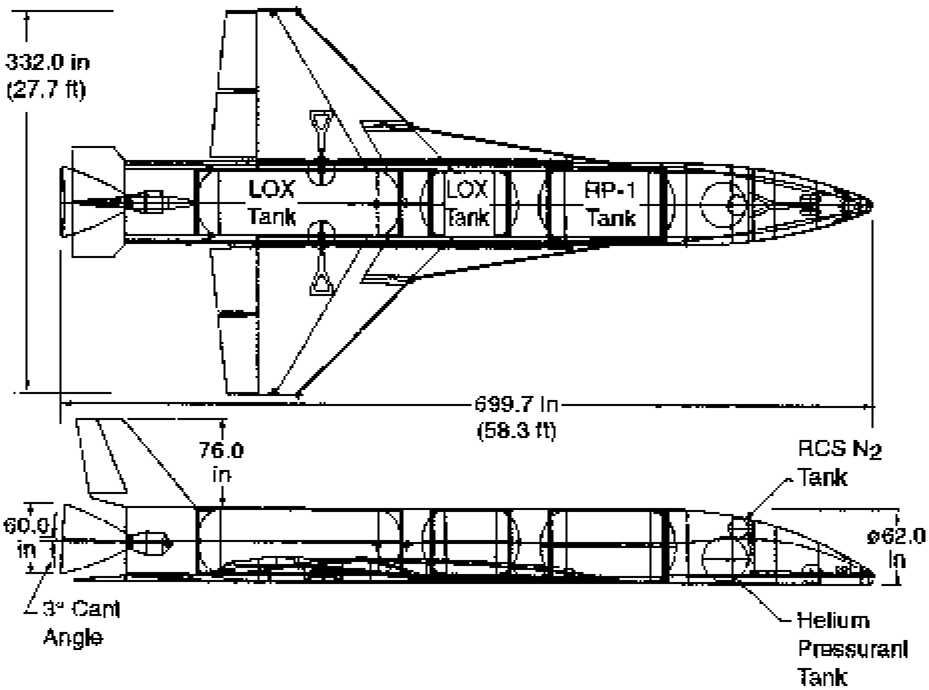


Figure 2.2: X-34 Expanded View

2.4 X-34 Propulsion

The FASTRAC engine is one element of NASA's Advanced Space Transportation Program, managed at MSFC. The program is designed to reduce the cost of space launch and develop technologies for space transportation needs for the next 25 years. Each FASTRAC engine (see Figure 2.3) initially will cost approximately $1 million -- about one-fourth of the cost of similar engines. The FASTRAC provides 60,000 pounds of thrust and, in addition to the X-34 vehicle, is targeted for launch systems designed to boost payloads weighing up to 500 pounds at a dramatically lower cost.

The modular X-34 design permits engine removal and replacement. It may be adaptable for subsequent testing of more advanced propulsion technologies such as rocket based combined cycle, plug nozzle, pulse detonation wave rocket, and dual expansion engines.

The FASTRAC thrust chamber assembly and nozzle are currently undergoing testing at MSFC. Other components, such as the LOX turbopump and gas generator have completed preliminary testing. The complete engine assembly will be tested at Stennis Space Center, in Mississippi, during the fall of 1998. The first engine hotfire is scheduled for September 1998.

FASTRAC 60K Engine

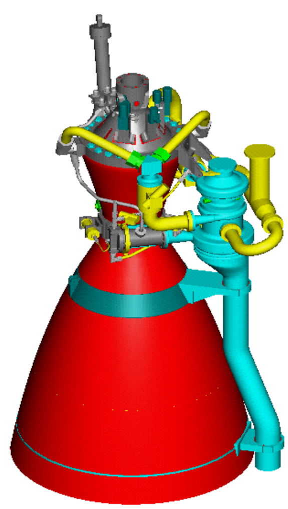


Figure 2.3 FASTRAC Engine

2.5 X-34 Operational Concept

The overall operational concept or approach to flight testing of the X-34 test bed demonstration vehicle is depicted in Figure 2.4

Specifically, the flight test program consists of two phases. In Phase I, the Baseline Flight Test Program, two flight vehicle airframes will be designed and built, and two envelope expansion flights will be conducted at White Sands Missile Range (WSMR) (see Figure 2.5). The first flight, an unpowered flight into White Sands Space Harbor (WSSH) using an engine simulator, is scheduled to be completed by March 1999. The second flight, the first powered flight using the MSFC FASTRAC engine, is designed to reach approximately Mach 2.6 and 85,000 ft altitude. This flight is scheduled to be completed by August 1999.

Phase II, the Optional Flight Test Program (OFTP), would provide for up to 25 additional flights to be completed within a one-year time period. The objective of the OFTP would be to demonstrate:

- autonomous flight operations, including return and landing to a designated landing site
- vehicle safe abort
- operations in expected RLV-type environments, such as landing in cross winds up to 20 knots and subsonic flight through rain and fog
- powered flight to at least 250 kft and Mach 8 or greater
- embedded RLV technologies and the ability to readily accommodate other RLV technologies

The OFTP remains an option in terms of the current contract. Thus, supporting analyses and decisions concerning possible test sites remain to be completed. However, one alternative that has received preliminary consideration involves operations out of the Eastern Range at KSC Cape Canaveral Air Force Station (CCAFS) as shown in Figure 2.6

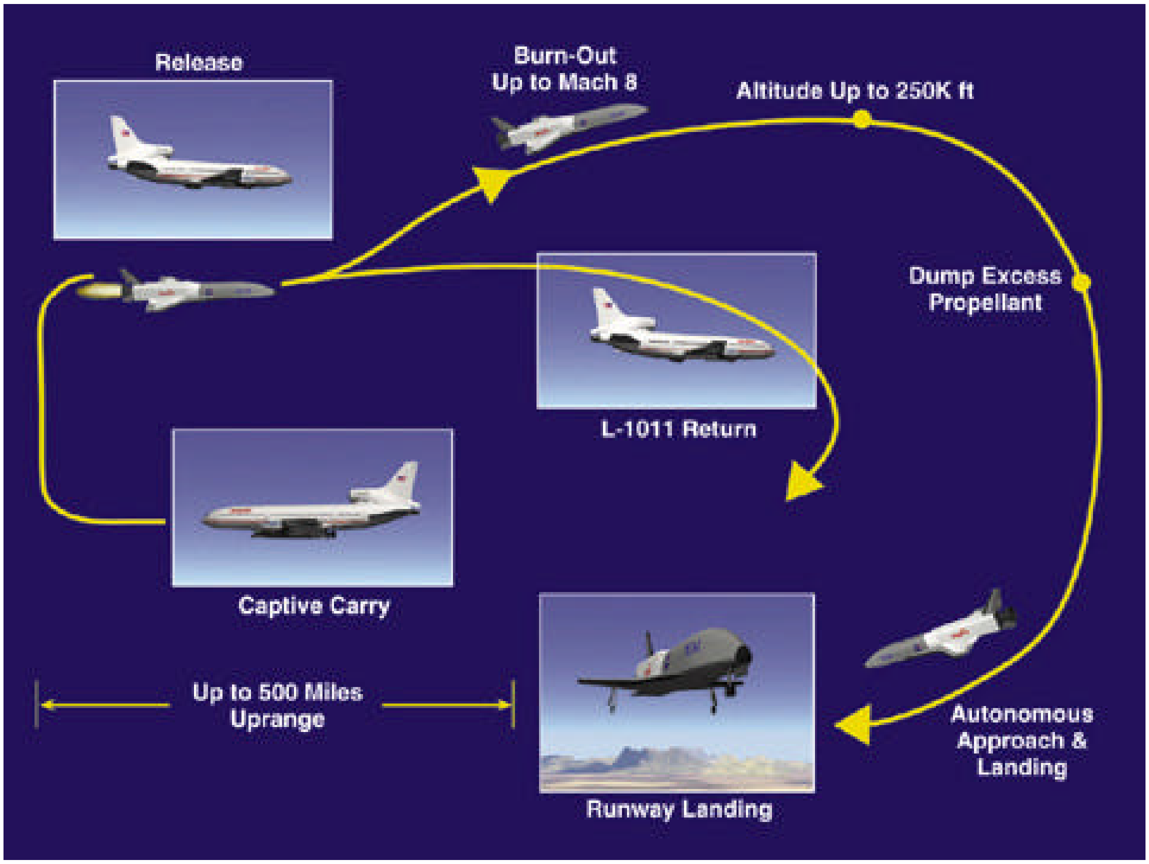


Figure 2.4 Operational Concept

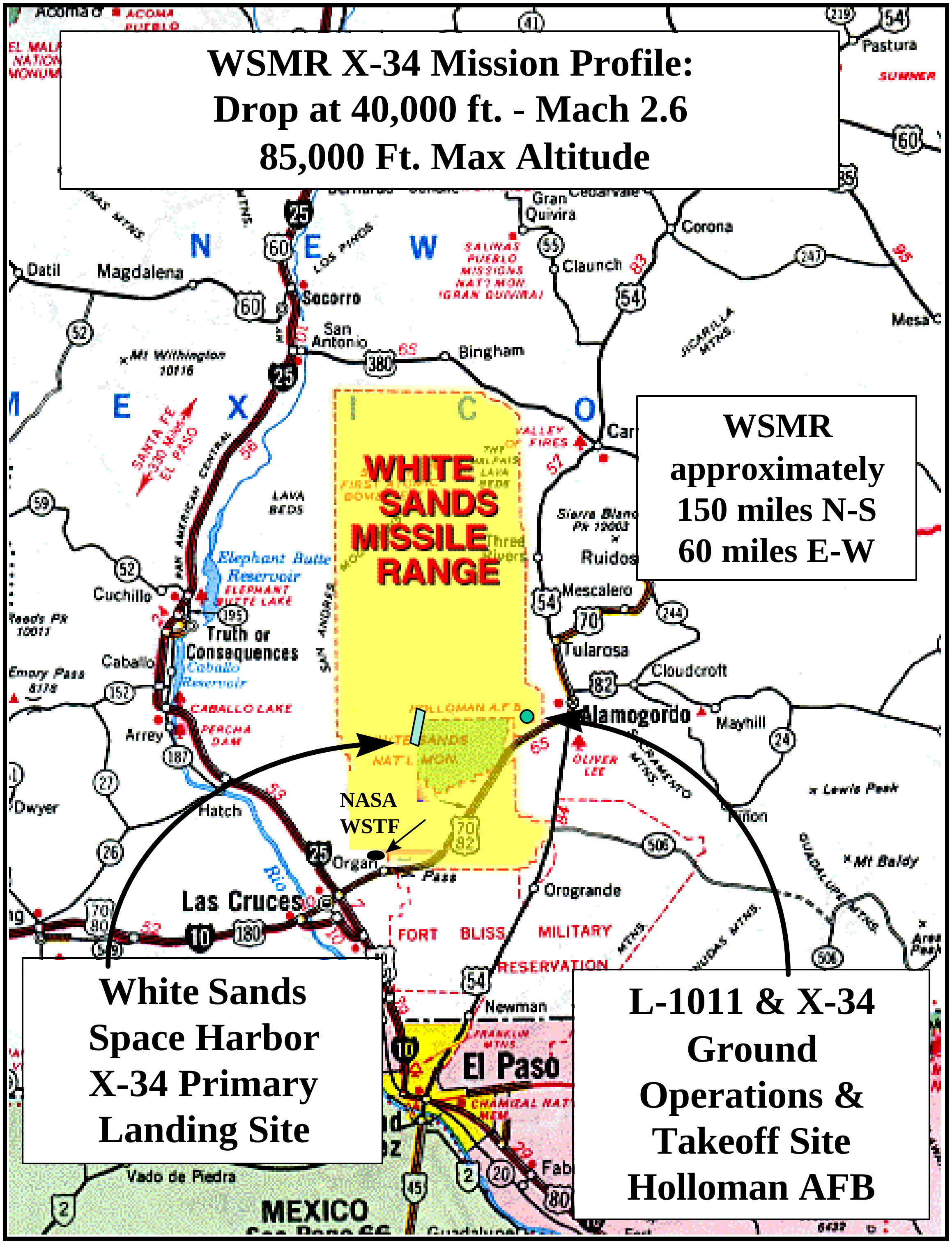


Figure 2.5 White Sands Missile Range Operations
(Baseline Flight Test Program)

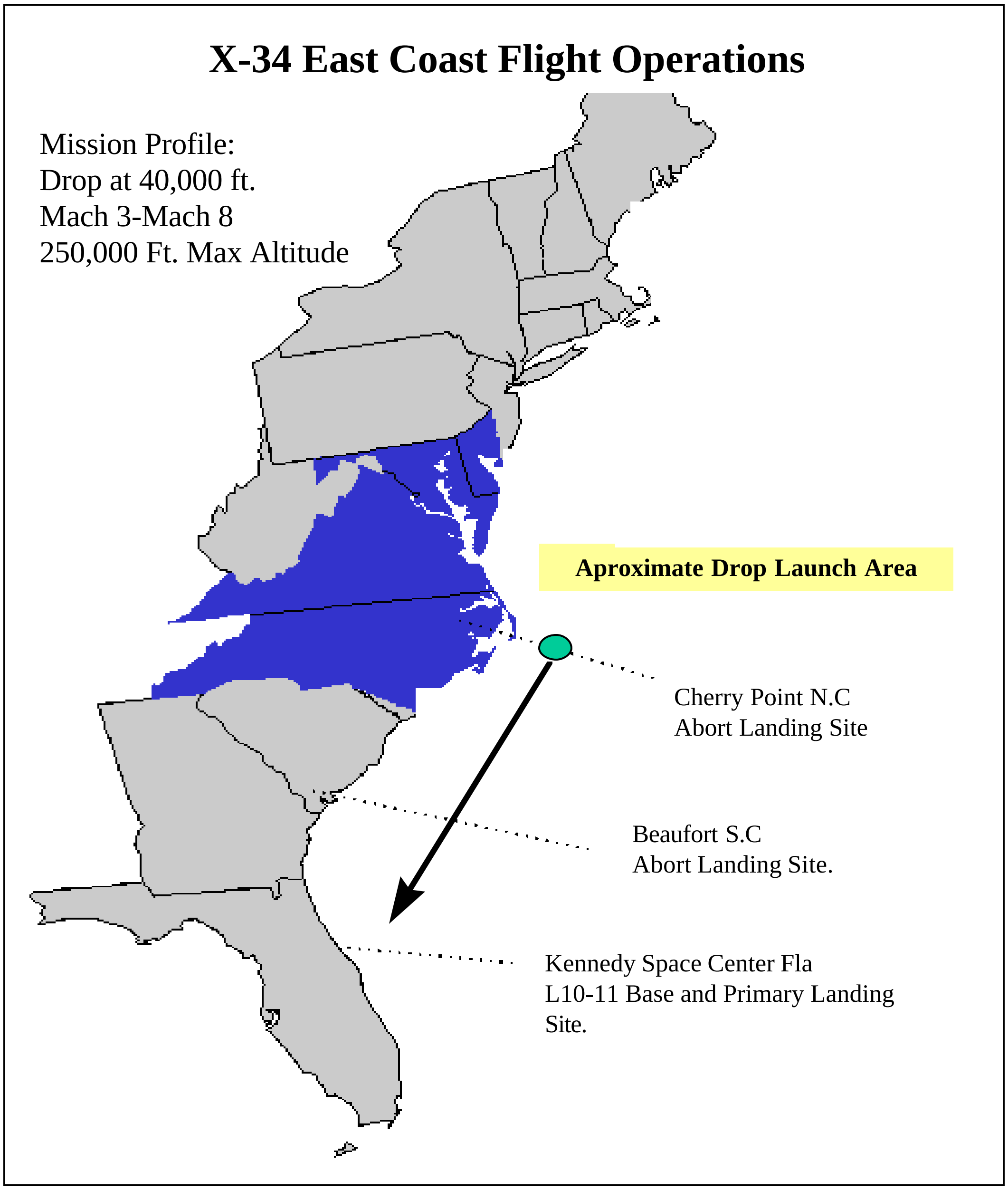


Figure 2.6 Eastern Test Range Operations

2.6 Range and Facilities

White Sands Missile Range is a multi-service test range whose main function is the support of missile development and test programs for the Army, Navy, Air Force, NASA, other government agencies and private industry. The White Sands range is under operational control of the U.S. Army Test and Evaluation Command (TECOM), Aberdeen Proving Ground, Maryland. TECOM is the Army's test laboratory for planning and conducting engineering and service tests of all materials from missiles to rifles, tanks to trucks, clothing to radios, and from aviation to fire control equipment. Holloman Air Force Base is located in the south-east corner of the WSMR and provides the pre-launch processing support for the L-1011/X-34 flight system.

White Sands Missile Range is in the Tularosa Basin of south-central New Mexico. The range boundaries extend almost 100 miles north and south and 40 miles east to west. At 3,200 square miles the range is the largest military installation in the country and could easily encompass the states of Delaware and Rhode Island. The headquarters area is 20 miles east of Las Cruces, New Mexico, and 45 miles north of El Paso, Texas. Additional callup areas are lands either privately owned or controlled by state and federal agencies. White Sands has contracts with ranchers in these areas which allow the range to evacuate the residents for up to 12 hours a few times a year for some tests. The ranchers are paid a yearly payment and travel expenses each time they evacuate. When utilized, the call-up areas add about 2,500 square miles for the range's temporary use. The only area regularly open to the public is the main post where there is a museum, missile park and White Sands National Monument.

White Sands Missile Range has more than 1,500 precisely surveyed instrumentation sites and over 1,000 of the newest and most modern types of optical and electronics instrument systems. These include long-range cameras, tracking telescopes, interferometer systems, radars and telemetry. For general use, radars, telemetry, and optic systems include both mobile and fixed systems. A timing system provides fixed-timing rates, elapsed time, and control signals. Control signals are combined into pulsed signals in standard format for distribution and utilization. Other range services include calibration, communication, meteorological, photographic, television and aerial target support along with the relatively easy and fast recovery of test items which facilitates evaluation.

3.0 X-34 Program Safety & Mission Assurance Processes

3.1 Overarching SMA Processes

3.1.1 SMA Process Maps

Figures 3.1-3.3 are process maps depicting the key elements in the overall X-34 Program safety, mission assurance, and risk management process. Figure 3.1 shows the internal OSC processes. Figure 3.2 depicts the task agreement (TA) relationships established by OSC to implement various Flight Assurance (FA)-related operational responsibilities. Figure 3.3 provides insight into the implementation of SMA processes on the FASTRAC engine program and the multiple roles played by the MSFC SMA office.

Salient features of Figure 3.1 include the central role of OSC FA as a participant in the concurrent engineering process and manager for system safety (ground/vehicle and range) planning and implementation. Also of central importance is the role of the Chief Engineer and the Systems Engineering Lead in managing the embedded risk management process through weekly meetings involving, system leads, working level sub-system managers, and top program managers. Figure 3.1 also captures the independent assessment role played by the Flight Assurance Advisory Board and the "hard-lined" reporting role of the Flight Assurance manager, who reports directly to the Vice President for the Advanced Projects Group (APG).

The extensive delegation of SMA functions to support organizations, as shown in Figure 3.2, is part of the overall Better/Faster/Cheaper approach of the X-34 program. Individual Task Agreements (TA) are managed by corresponding OSC engineering leads who have "dotted line" or indirect reporting relationships to the OSC/FA manager. It is noteworthy that MSFC SMA serves in a sub-contract role to OSC in providing SMA support to the Main Propulsion System (MPS) development.

Figure 3.3 shows how MSFC SMA simultaneously provides support to the MSFC FASTRAC program office while providing overall X-34 SMA support to the MSFC X-34 Program Manager. The three roles:

- MPS SMA support,
- FASTRAC SMA support, and
- overall SMA support to the X-34 Program

represent an inherent conflict of interest when performed by the same individual.

3.1.2 Concurrent Engineering Process

The X-34 Program is an excellent example of the Better/Faster/Cheaper concurrent engineering environment where large formal board meetings (Configuration Control, Engineering Change, etc.) are replaced with more numerous small meetings, formal and informal, where design and manufacturing issues are resolved. The key to making this work is a central configuration management system, shared CAD design tool suite, and a process which everyone seems to understand. The X-34 Program has three regularly scheduled weekly meetings which provide a relatively "short cycle" risk management/program management control process. The OSC FA manager attends all of these meetings.

Monday: Engineering Review: (serves as the Risk Management Forum)

The engineering review is attended by all system Team Leads along with the Chief Engineer, Systems Engineering Lead, and Flight Assurance Manager. If issues fall within budget constraints, the Chief Engineer is the risk decision executive. If issues have budgetary implications, the Orbital X-34 Program Manager is responsible for the resolution. If the issue is out of contract scope, the NASA X-34 Program Manager must resolve the issue.

Tuesday: Sub-System Review: (serves as the Concurrent Engineering Forum)

The sub-system review is the main concurrent engineering forum. Specific sub-system engineering and design issues are addressed and in most cases resolved at this level. This meeting is typically structured as an in-depth technical review of sub-system issues, and interfaces and integration with other sub-systems.

Wednesday: Senior Management Review

Technical and risk management issues are the primary focus of this meeting. Administrative and future business issues are also addressed. The meeting is briefed to the Senior Vice-President of APG and to the Corporate Technical Officer, and is attended by X-34 Program Manager, Deputy Program Manager, the Chief Engineer, the Lead Systems Engineer, and the Flight Assurance Manager.

Monthly: NASA Program Management Review

In addition to the weekly meetings, OSC provides a monthly briefing to NASA X-34 program management. This meeting typically addresses schedule and cost issues and serves to resolve "out of scope" needs identified by OSC. This meeting includes the OSC X-34 Program Manager, Deputy Program Manager, the Chief Engineer, the Lead Systems Engineer, and the Flight Assurance Manager

Abbreviations used in Figures 3.1-3.3

FA: Flight Assurance / CE: Chief Engineer / SE: Systems Engineer
PM: Program Manager / TPS: Thermal Protection System
GN&C: Guidance Navigation & Control
EIS: Environmental Impact Statement / FONSI: Finding of No Significant Impact
LOX: Liquid Oxygen / GSE: Ground Support Equipment / OPS: Operations

GFE: Government Furnished Equipment

Figure 3.1

X-34 Flight Assurance & Risk Management Process Map

(Safety is an integral part of the OSC Flight Assurance model)

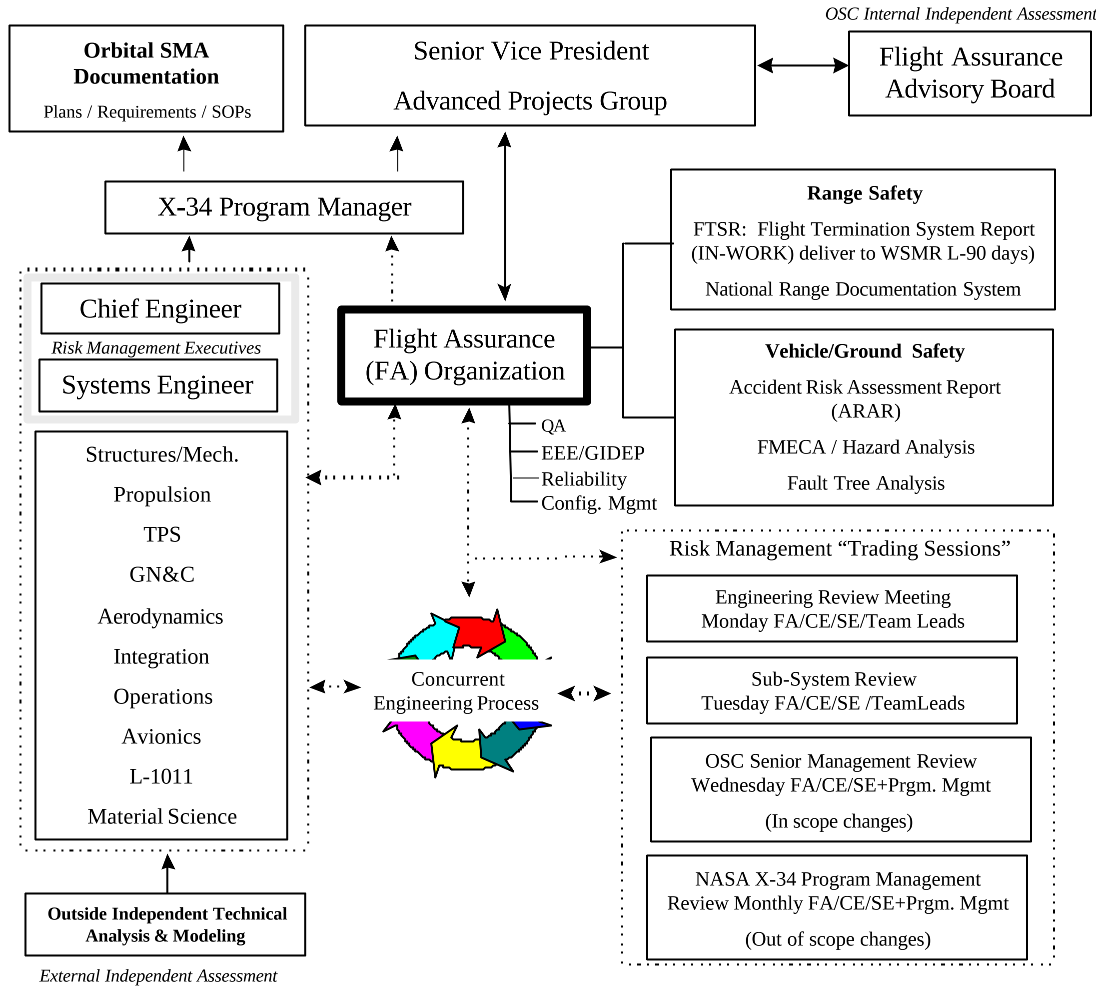

OSC Internal Independent Assessment
Orbital SMA Documentation
Plans / Requirements / SOPs
Senior Vice President
Advanced Projects Group
Flight Assurance Advisory Board
X-34 Program Manager
Range Safety
FTSR: Flight Termination System Report (IN-WORK) deliver to WSMR L-90 days)
National Range Documentation System
Chief Engineer
Risk Management Executives
Systems Engineer
Flight Assurance (FA) Organization
Vehicle/Ground Safety
Accident Risk Assessment Report (ARAR)
FMECA / Hazard Analysis
Fault Tree Analysis
QA
EEE/GIDEP
Reliability
Config. Mgmt
Structures/Mech.
Propulsion
TPS
GN&C
Aerodynamics
Integration
Operations
Avionics
L-1011
Material Science
Risk Management "Trading Sessions"
Engineering Review Meeting
Monday FA/CE/SE/Team Leads
Concurrent Engineering Process
Sub-System Review
Tuesday FA/CE/SE /TeamLeads
OSC Senior Management Review
Wednesday FA/CE/SE+Prgm. Mgmt
(In scope changes)
NASA X-34 Program Management
Review Monthly FA/CE/SE+Prgm. Mgmt
(Out of scope changes)
Outside Independent Technical Analysis & Modeling
External Independent Assessment

Figure 3.2

X-34 Flight Assurance & Risk Management Process Map
Extension to Supply Chain and Supporting Task Agreements

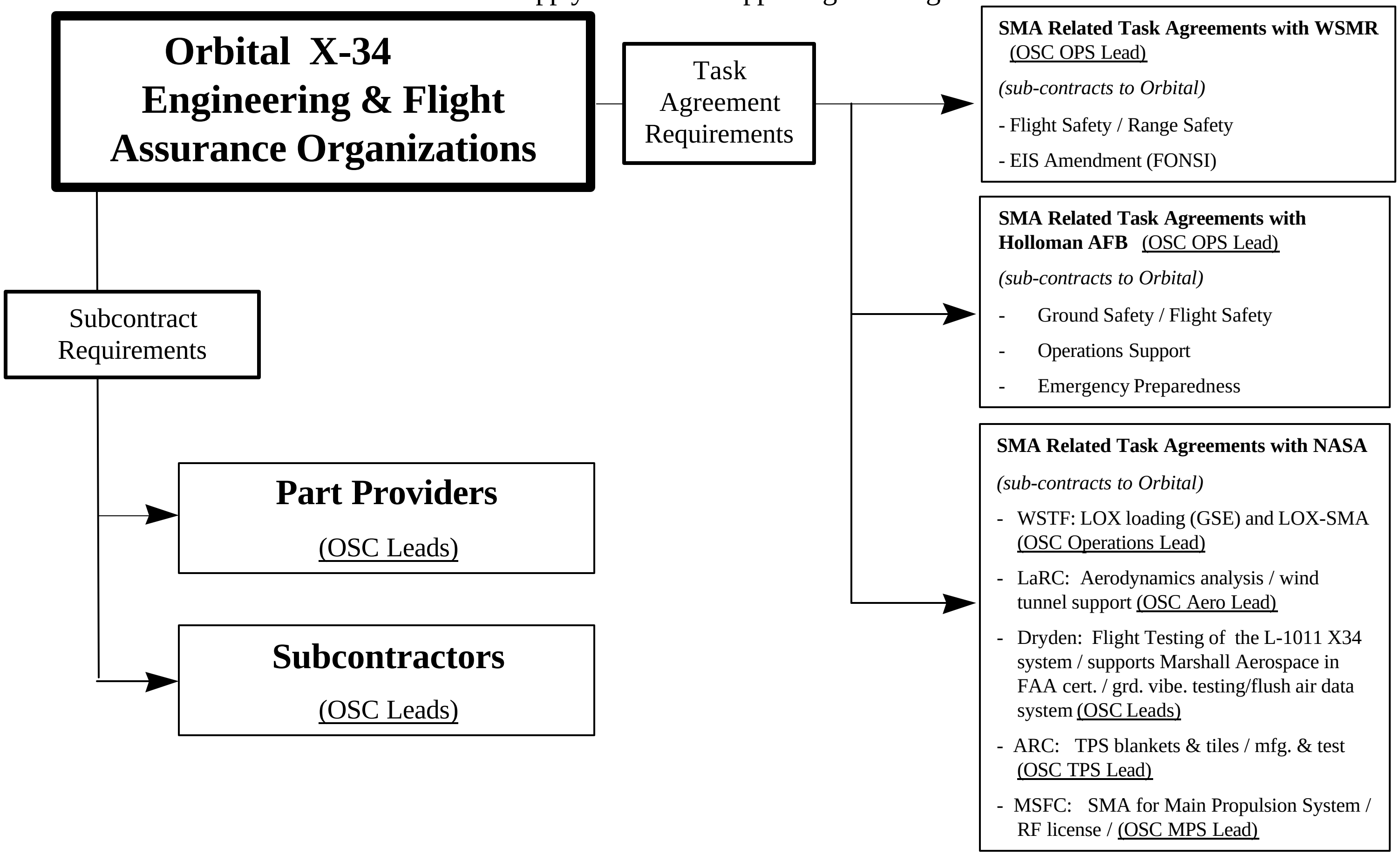
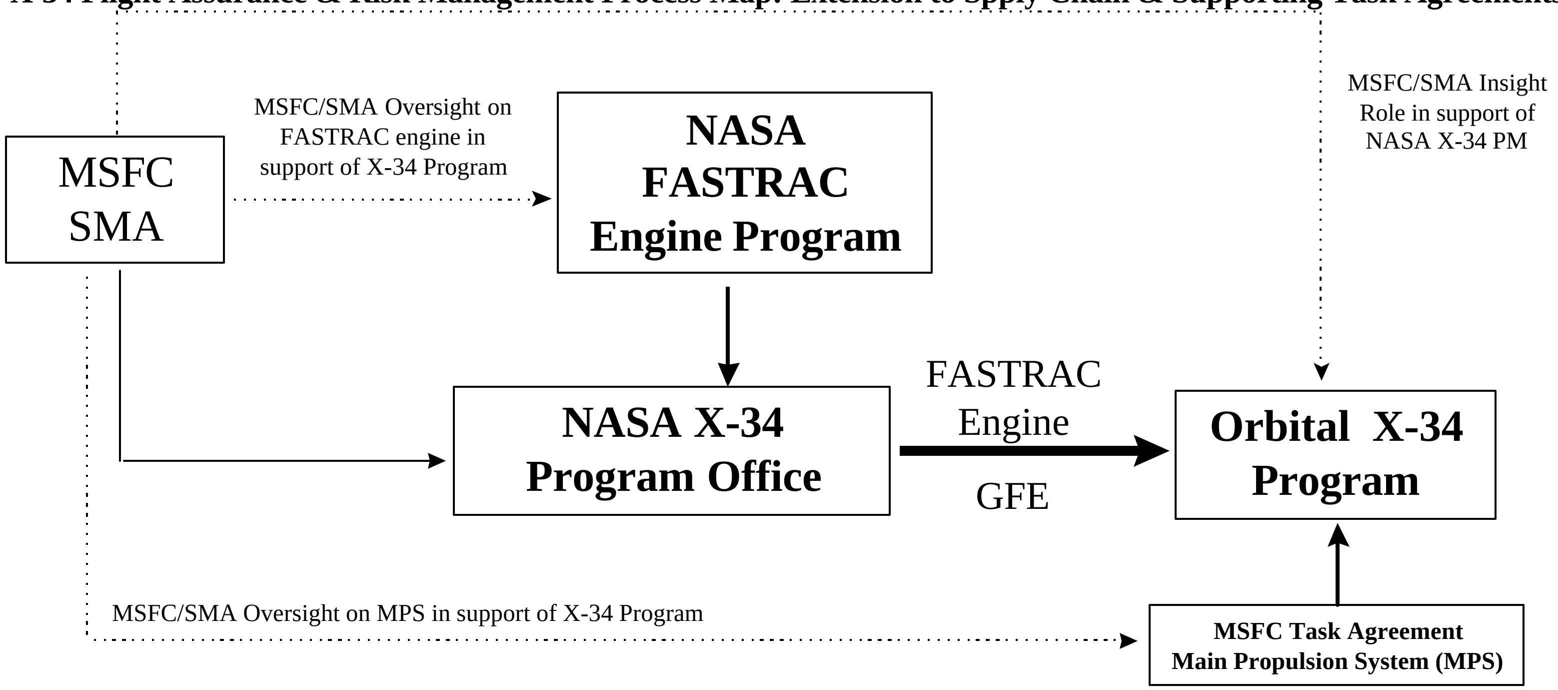


Figure 3.3

X-34 Flight Assurance & Risk Management Process Map: Extension to Spply Chain & Supporting Task Agreements



SMA Insight

Acquiring an *understanding* of safety, mission assurance and risk management processes employed by the performing organization over the life-cycle of a program. Acquiring *visibility* into the implementation of those processes. Developing an understanding of key safety and mission assurance issues associated with the program.

SMA Oversight

Using *customer-imposed* product specifcations and process controls, such as MIL-Specifications, MIL Standards and mandatory inspections, to *direct* the development of the product. Developing an understanding of key safety and mission assurance issues associated with the program.

3.1.3 Risk Management Process

OSC does not have a formal risk management plan for the X-34 program. However, all the steps of an adequate risk management process are in place and functioning; these include risk identification, analysis, planning, tracking, controlling, and documentation and communication. Risk identification includes safety risks from the FMECA, hazard analysis, and fault tree analysis provided by Flight Assurance; contract/schedule/cost risks from Weekly Management Reviews; and current and potential risks from Weekly Engineering Meetings.

Risk analysis includes ranking risks in a Watch List (see example in Figure 3.4). This list identifies each risk area, current rank, prior rank, consequence, current mitigation approach (and additional mitigation actions, if required), mitigation costs, and date of last update. Additional Watch List fields, not shown in the example, were said to include a categorization of the risk: safety, technical, or programmatic. In order to rank them in the Watch List, risks were assessed for their probability and impact by the Chief Engineer and the Systems Engineer. Note that this assurance process is not formally documented.

Decisions on risk mitigation may also be found in the Issues/Decision Log (Figure 3.5). This log is designed to provide an efficient and effective mechanism for concisely defining and communicating risk issues, identifying affected interfaces; e.g., Flight Assurance, summarizing required updates, and succinctly describing the risk decision status (possibly including mitigation actions). It also identifies programmatic impacts, which include check-blocks for "cost," "schedule," "contracts," and "no impact," but not for "safety".

Risk tracking is satisfied through the monitoring of metrics called Technical Performance Measures (TPM) (see Figure 3.6). Risk control appears to be well-integrated into the normal course of project activities; e.g., weekly engineering meetings, weekly program reviews, and monthly project office reviews.

Documentation and communication of risks is accomplished by means of the Issues/Decision Log (with open issues/decisions e-mailed to affected parties weekly), the TPM Tracking File which is updated monthly, the Watch List, Engineering Meeting minutes, and the weekly and monthly briefings at Program Reviews and Project Office Reviews.

Figure 3.4 Risk Management Watch List

Rank (5/1/98)	Prior Rank (3/3/98)	Risk Area	Risk Consequence	Current Risk Mitigation	Additional Risk Mitigation	Cost of Additional Mitigation	Updated
1	1	FASTRAC Engine Availability	Program Delay	X-34 FASTRAC Engine Given 2nd Highest Priority at MSFC. C&V Schedule allows greater margin in Engine delivery date since Engine not required for first flight.	Use of NK-39 Engine to Mitigate Technical Risk		Jan 12 1998
2	2	Engine Operability & Maintainability Requires engine removal, disassembly, assembly & integration.	Increased Turnaround Times		Use of NK-39 Engine to Enhance Operability		Jan 12 1998
3	9	High Speed Corridor Approval / OFTP Commitment	Delay in Off Range flights / EIA is a 2 year process. Need to have OFTP option exercised ASAP to ensure that EIA/EIS is completed in time for the off WSMR flights. Need to ascertain mid range telemetry capability for off WSMR flights.	Low Mach # flights performed within WSMR. High Mach # flights planned at KSC. Mid Range Mach # flights require High Speed Corridor Approval.			May 1 1998
4	11	Lack of Spares for OFTP, EFTP	Delays in Flight Turnaround Operations. Increased Cost of Expedited Components.	None	Procure Spares in Conjunction with Planned Buys of Vehicle 1 and 2 Hardware	TBD	May 1 1998
5	4	Vehicle Mass Growth	Vehicle performance decrease. Inability to eventually attain Mach 8.0.	8.76% Mass Margin (Weight Empty) Remains. Increasing Pressure To Maintain Mass Targets. Assessing Mass Saving Options for A-3 Which Will be Targeted as High Performance Vehicle	Use of NK-39 Engine With Significantly Higher Thrust to Weight Ratio. Mass Optimized 2nd Version of FASTRAC Engine. Purchase a 3rd Wing.		May 1 1998

Figure 3.5 Risk Management Decision Log

Input Form:

Group: Thermal **Entered By:** Rahal **Date:** 5/19/1998

Title: Metallic TPS close outs

Issue: The strake is not conducive to softgoods TPS closeouts due to conflicting requirements - 1) remove blankets without damage, 2) leave no open fastener holes.

Interim Decision : 3/4" HHB will be affixed to strake up to fastener pattern where FRSI will be applied and punched for access to fastener holes. OSC will provide metallic closeouts over open holes.

Decision Status: ☒ Negotiated Decision

Updates Required
- ☐ Drawing
- ☐ Specification
- ☐ ICD
- ☐ Requirements
- ☒ Mass Props
- ☐ No Update

Affected Interfaces
- ☐ Flight Assurance
- ☐ Systems Eng
- ☐ L-1011
- ☐ Ops/Facilities
- ☐ Integration
- ☐ Test
- ☐ Structures
- ☒ Fuselage
- ☐ Control Surfaces
- ☐ Landing Mech.
- ☐ Tanks
- ☐ Wing
- ☒ TPS
- ☐ Propulsion
- ☐ Avionics
- ☐ Hydraulics
- ☐ GN&C
- ☒ Aerodynamics

Programmatic Impacts
- ☐ Cost
- ☐ Schedule
- ☐ Contracts
- ☐ No Impact

Submit Decision

Cancel

Instructions

Log Entry:

Item	Group	IssueDate	IssueAuthor	IssueTitle	InterimDecision/Response	Finalized	Mass	FA	Sys Eng	L-1011	Ops	Integ	Test	StructSys	Fuselage	Wing	CSurf	Tanks	LMechm	Thermal	Prop	Avionics	Hyd	GN&C	Aero
633	Thermal	5/19/98	Rahal	Metallic TPS close outs	3/4" HHB will be affixed to strake up to fastener pattern wher FRSI will be applied and punched for access to fastener holes. OSC will provide metallic closeouts over open holes.	x	x								x					x					x

Figure 3.6 Technical Performance Measures

TPM Status	Target	Units	X1 9/2/96	X3 11/21/96	X5 12/3/96	X7 12/12/96	X9 3/3/97	X11 4/29/97	X13 7/1/97	X15 10/2/97	X17 12/19/97	X19 2/27/98	X21 4/24/98
Maximum Mach Number* vs. Mach 8	>8	#	8.40	8.40	7.90	7.60	7.50	7.87	7.40	7.20	6.95	7.06	7.13
Engine Isp	>310	sec	310	310	310	310	310	314	314	314	314	314	314
Engine Thrust	60 -68	Klbf	60.0	60.0	60.0	60.0	60.0	63.9	63.9	63.9	63.9	63.9	63.9
Weight Empty Margin Depletion*	Profile	%	22.35%	21.06%	18.97%	19.15%	17.86%	16.68%	15.53%	13.50%	11.03%	9.82%	8.76%
Weight Empty* vs. Mach 8 Reqt	3000lbs/M	lbs	15132	16113	16017	16475	16210	16478	17293	17815	18058	17903	17747
Weight Empty (NC) vs. Mach 8 Reqt	3000lbs/M	lbs	12368	13309	13463	13827	13753	14125	14969	15696	16263	16302	16317
Total Usable Propellant vs. Mach 8 Reqt	xlbs/M	lbm	29000	29000	27500	27500	27772	27816	27977	27977	27977	27977	27977
Drop Gross Weight*		lbs	44766	45776	44517	45119	45132	45061	46886	47171	47413	47259	47102
Captive Carry Propellant Losses		lbs	1896	1896	1896	1896	1763	1763	1764	1766	1766	1766	1766
Max Gross T/O Weight* vs. L-1011 Capability	52000	lbs	45876	46887	46969	47571	47312	47508	48650	48937	49179	49025	48868
Mass Fraction*		%	0.65	0.63	0.62	0.61	0.62	0.62	0.60	0.59	0.59	0.59	0.59
Max Landing Weight* vs. Gear Capability	22693 (@6 fps)	lbs	16619	17629	17711	18313	18054	18141	19585	20030	20138	19984	19827
Max Landing Speed* vs E/F Tire Limit (w/o drag chute)	<230	Knots	N/A	N/A	203	203	203	203	198	198	198	198	198
Cg (drop) vs. Target Range	396+/-6	inch	400.69	401.10	393.11	396.04	394.80	398.30	399.40	403.50	403.00	402.90	404.20
Cg (landing) vs. Target Range	416+/-6	inch	434.60	437.40	413.37	413.14	410.40	412.00	418.70	426.40	425.00	424.90	424.30

3.1.4 Independent Review Processes

As currently implemented, the X-34 program has both internal and external independent review processes.

External Reviews

At the request of the Associate Administrator for Aeronautics and Space Transportation Technology (Code R), an Independent Technical Assessment Advisory Group was formed at Langley Research Center and chaired by Darrell Branscome. This external independent review team participated in the Outer Mold Line Freeze, December 1996 and the System Design Freeze completed in May 1997. While these two reviews focused on key programmatic and technical design and development areas, the team highlighted several safety and mission assurance issues. All issues were captured through the formal Review Action Recommendations (RAR) process which is described in detail in a subsequent section of this report. In addition, the review team has provided a separate write-up for each review.

Code R also chartered an independent review team to evaluate risk reduction approaches and assess the merit of conducting the optional flight test program. Chaired by Mr. Robert Meyer (Dryden Flight Research Center), the team included members from ARC, DFRC, KSC, JSC, LaRC, LeRC, and MSFC. This review was completed in March 1997. The team was reconvened to assess various X-34 aero-science experiments and operations technologies opportunities. This review was completed in April 1998.

OSC undertook a separate independent review of the X-34 wing design. The wing design is unique because of the requirement to accommodate the trade between the LOX tank diameter and available ground clearance limits for the vehicle when mounted under the L-1011 carrier aircraft. Quartas Engineering conducted this review from December 1997 through May 1998. Quartas Engineering analyzed the wing carry-through spar and the wing/fuselage interface and considered material and design load allowables, factors of safety, finite element model (FEM) approaches and overall design philosophy. The review team determined that each of these areas has been satisfactorily addressed and considers the overall wing design to be sound.

The MSFC Payload Assurance Office conducted a quality assurance audit in November 1997. This review focused on the quality system being implemented for the X-34 program at the OSC facility in Dulles, Virginia. While the findings from this audit were largely positive, several areas were identified as needing attention. The MSFC X-34 Program Office and OSC have addressed and appropriately dispositioned each of the findings and observations.

Internal Reviews

OSC has a formally established Flight Assurance Advisory Board. This Board reports to Dr. Antonio Elias, Senior Vice President of APG and is comprised of the Flight Assurance Directors from the Launch Systems Group and the Space Systems Group, Mr. David Low and Tom Manson, respectively. Two other senior-level individuals, Mr. Alton Jones and Mr. John Boechel, complete the membership of the Board. The purpose of the Board is to advise the Senior Vice President of APG on issues of safety and mission assurance relative to the various flight projects under his perview.

OSC has formed an internal assessment team, known as the "Blue Team" to participate in various major program reviews. The Blue Team parallels the Independent Technical Assessment Advisory Group, chaired by Darrell Branscome. The team is made up of members from OSC and MSFC who are not directly involved in the X-34 program. To date this review team has participated in each of the major program reviews, (i.e. System Requirements Review, Outer Mold Line Freeze, and System Design Freeze) and will participate in the System Verification Review when scheduled. This team provides its inputs/comments/concerns through the formal RAR process.

3.1.5 Configuration and Data Management

Configuration and data management (CM/DM) for the X-34 Project is accomplished in accordance with OSC Advanced Projects Group (APG) Configuration and Data Management Standard Operating Procedures (TD-9007 Rev A). Unique X-34 Program CM/DM requirements and procedures are identified in the X-34 Program Configuration and Data Management Plan (TD-9102 Rev A). This plan, prepared in conformance with MIL-STD 973, describes the X-34 CM organizational structure, program unique configuration identification, control, status accounting procedures, and configuration audits for technical description data.

Configuration Baselines

As defined and implemented by OSC on the X-34 Program, a configuration baseline represents a configuration identification document or a set of technical documents formally designated and fixed at a specific time during a Configuration Item's (CI) life cycle. Baselines establish a point of departure for the control of subsequent changes and facilitate accounting for the incorporation of approved changes. Thus, the initial baselines, plus approved changes to those baselines, constitute the current configuration identification.

Functional and Allocated Baselines

The performance, design, development, and test requirements for the X-34 System are defined in the X-34 System Specification (X60005). The configuration thus defined constitutes the Functional Baseline - or the initial Functional Configuration Identification FCI). At any point in the X-34 system life cycle the current FCI can be defined as the initial Functional Baseline plus all approved changes to that baseline.

These same requirements are then allocated to the main functional segments or configuration items (CI) which consist of the 1) X-34 Vehicle, 2) X-34 Carrier Aircraft (L-1011), and 3) X-34 Operations and Facilities. The performance, design, development, and test requirements of these configuration items are documented in the segment specifications X60006, X60007, and X60008 respectively. These specifications constitute the CI's Allocated Baseline, also known as the initial Allocated Configuration Identification (ACI). As described above, at any point in the CI"s life cycle, the current ACI is defined by the Allocated Baseline plus all approved changes to that baseline.

Product Baseline

The Product Baseline or initial Product Configuration Identification (PCI) for the X-34 system is defined as the "as-built" configuration of each segment or CI for the first powered flight mission (vehicle A2), i.e. as-built for the powered flight vehicle, as-modified for the carrier aircraft, and as-built ground support equipment. The as-built configuration is documented at the integration facility by the vehicle log which includes the quality records of all items delivered to the facility, the integration procedures use to build that CI, the complete work orders where applicable, Non-Conformance Reports (NCR), Field Discrepancy Reports (FDR), and the vehicle weight logs.

Subcontractor Design Baseline

OSC requires a design baseline for those subcontractors responsible for both design and manufacturing of a CI. This enables OSC to be involved with change control prior to the formal establishment of the product baseline for the configuration item of interest. This design baseline is established upon OSC receipt and approval of the subcontractor's design data package.

Configuration Control Classifications

Change control is implemented on all segment and lower-level configuration items. The classification of X-34 internal engineering changes generally follows the guidelines of MIL-STD 973 with minor modifications as defined below:

> Class I - Any technical change to the Functional or Allocated Baseline outside of specified limits or tolerances is considered a Class I change. After establishment of a subcontractor design baseline or product baseline a change to any document or piece of software is defined as Class I if it affects the CI's interchangeability, performance, reliability, safety, mass properties (significantly), electrical or mechanical interfaces, electromagnetic characteristics or qualification status.

Class II - Those changes which do not fit into the Class I category

Class I changes require Orbital approval and Class II changes require Orbital classification concurrence.

Engineering Change Notice

Class I engineering changes must be approved by the program manager or his designee prior to incorporation into the released documentation. This approval is obtained by submitting an Engineering Change Notice (ECN). The ECN is the principle configuration management tool for recording, approving and releasing changes to formally released drawings and engineering documentation. The program Configuration Administrator maintains a database of all ECNs. The ECN is logged into the database and a copy of the ECN is filed. Action items associated with any deferred ECN are contained in the Configuration Control Board meeting minutes. The actionee is responsible for providing the information or documentation necessary to resolve the action to the Configuration Administrator so the deferred ECN can be resolved at the next Configuration Control Board meeting. The status of the ECN is updated in the database until all impacted drawings identified in the ECN have been changed.

Configuration Control Board

The Configuration Control Board (CCB) reviews all proposed Class I engineering changes to the established engineering baseline. The CCB is the forum for all program technical areas to evaluate proposed changes and discuss the overall system-level impact of the proposed change and either approve or disapprove the change.

The X-34 program Configuration Control Board is comprised of the following members: Chief Engineer, Flight Assurance Manager, Configuration Administrator, Lead System Engineers, and Segment Level Lead(s) (Vehicle, Operations, L-1011) as required.

The X-34 Program Manager has delegated his responsibility as the CCB chairman to the X-34 Chief Engineer. As such, the Chief Engineer’s signature is required to approve any proposed Class I change to baselined engineering. It is the chairman’s responsibility to convene the appropriate members of the CCB at the appropriate frequency to provide him with sufficient council to determine the disposition of proposed changes. The participation of the engineering staff will be determined by the scope of the change. It is he chairman’s prerogative to approve/disapprove an ECN without formally convening the Board. The CCB/ECN process is described in Figures 3.7 and 3.8.

Figure 3.7 Configuration Control Process

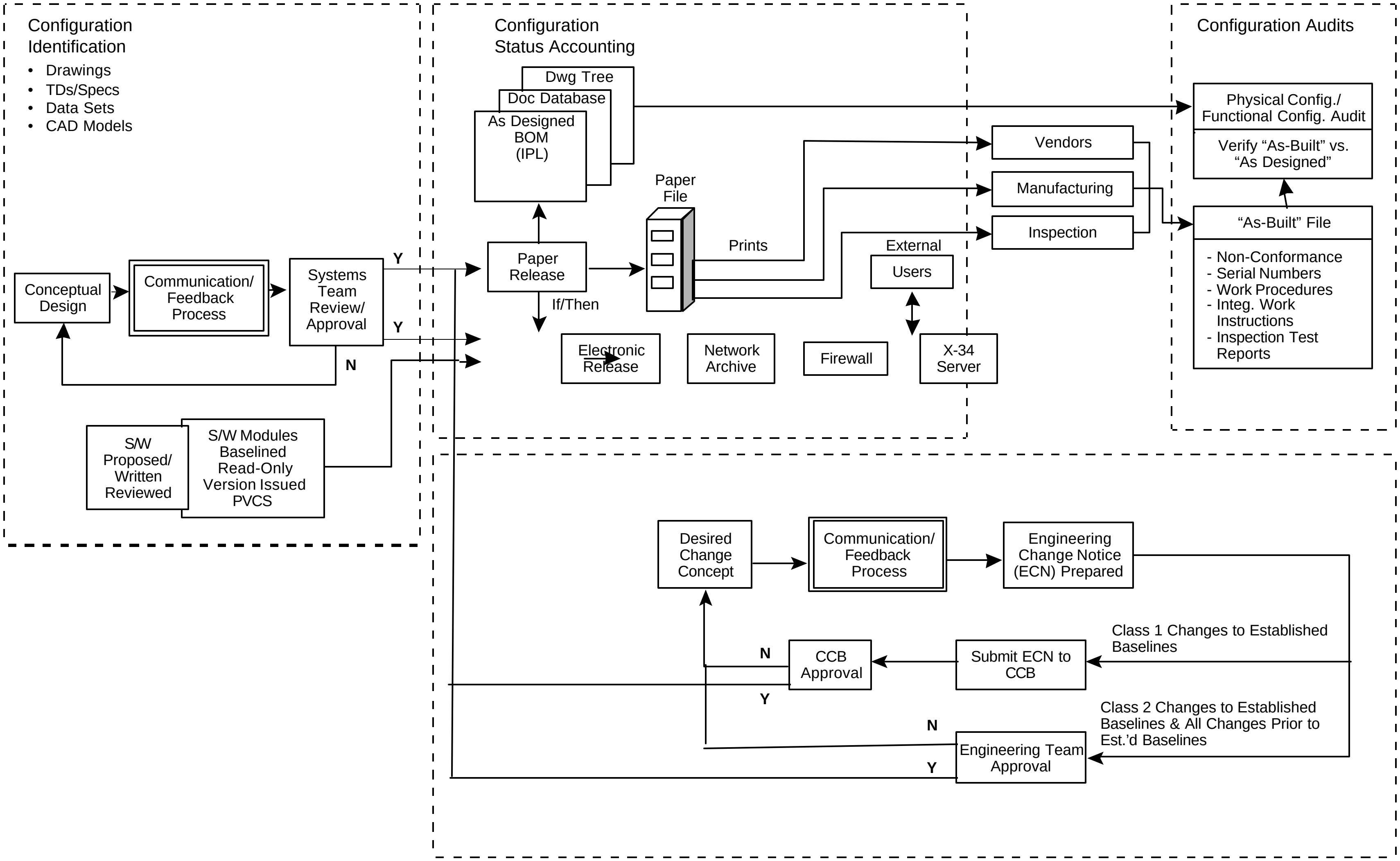
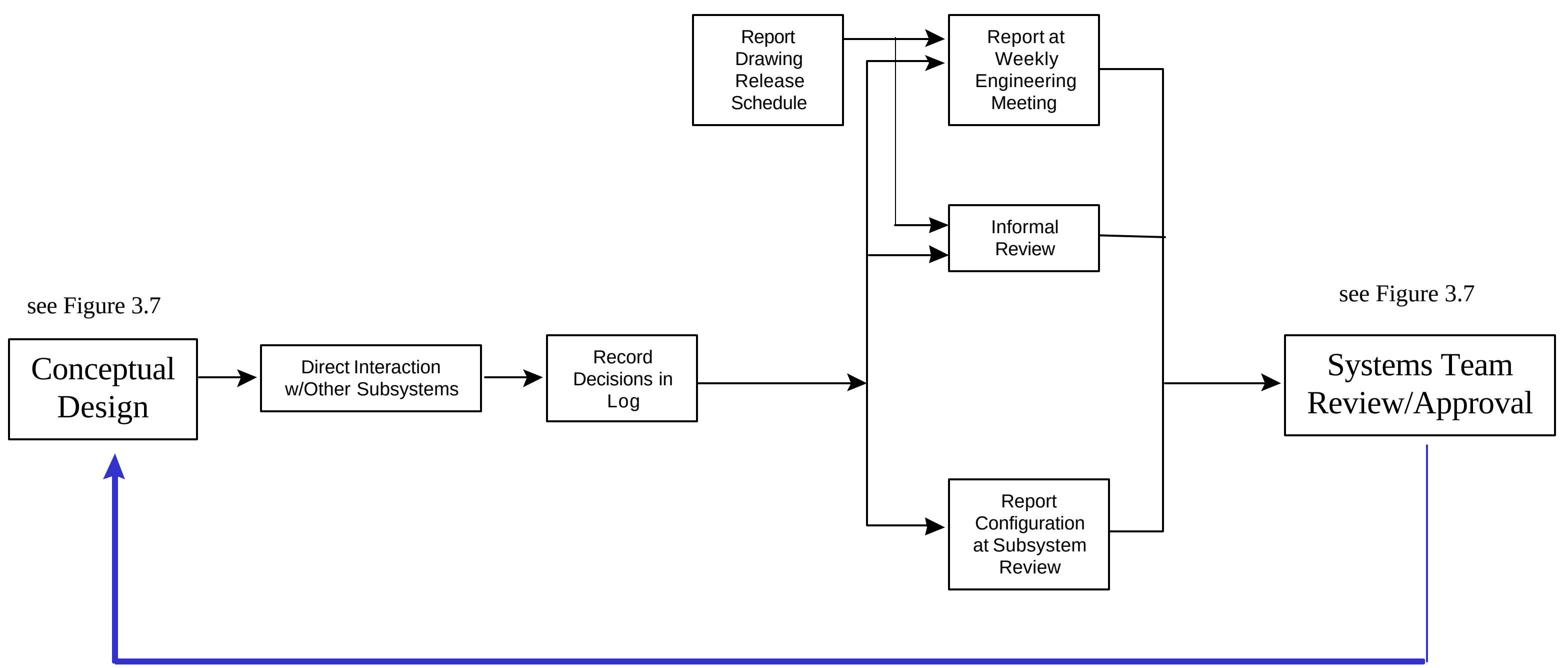


Figure 3.8 Communication/Feedback Process



Electronic File Control

All personnel have accounts on the NOVELL server/network which permits access to subdirectories which are established to assist in electronic configuration control. In addition, an NT server/network exists which links all computer-aided design (CAD) stations utilizing the IDEAS CAD software tool to facilitate CAD mechanical drawing storage, control, and access. Specific network directories exist for CM released electronic files. In order to maintain data integrity, users have restricted read and write privileges in various subdirectories. The ORCAD system is used for the design and control of electrical parts, electrical subassemblies, and schematics.

Non-Conformance Report (NCR) and Field Discrepancy Report (FDR)

NCRs and FDRs are used for identifying discrepancies between as-designed and as-built configurations. NCRs are used to identify discrepancies with items that are received or processed at OSC's Dulles facilities. FDRs are used to identify discrepancies with items that are received or processed at field site facilities. An NCR or FDR written against an error on a drawing can not be formally closed until the documents identified on the NCR or FDR has been changed via the CCB/ECN process.

The X-34 NCR format is the same as that used by all programs in the Space Systems Group at Orbital and consists of the following elements:

- Section 1 - Detailed Description of Discrepancy
- Section 2 - Disposition of Discrepancy
    - -- MRB (Use-as-is or Repair) - Requires concurrence of Subsystem Lead Engineer and Flight Assurance Manager
    - -- Non-MRB (scrap, return to vendor, rework) - Requires concurrence of Cognizant Engineer and Quality Assurance
- Section 3 - Cause and Corrective Action
    - -- Identification of the root cause of the discrepancy
    - -- Corrective action to be taken to prevent recurrence
- Section 4 - Close Out
    - -- Final acceptance of implemented corrective actions

The NCR and FDR database will be maintained at the Dulles facility using the Orbital Technical Information System (OTIS).

L-1011 Aircraft Configuration Control

An X-34 Vehicle/L-1011Aircraft Interface Control Document (ICD) is prepared and controlled in accordance with the configuration control processes described herein. Prior to first time release and release of changes, the ICD required approval signatures from both sides of the vehicle/aircraft interface. Engineering documentation and software associated with any X-34 related modifications to the L-1011 will be generated and controlled per the L-1011 Aircraft Configuration Management Plan (TD-0221).

Configuration Audits

There are two basic types of configuration audits performed internally by OSC for the X-34 program.

The Physical Configuration Audit (PCA) is the comparison of actual hardware to the released engineering drawings that define the desired configuration:

- The Quality Assurance (QA) engineer performs incremental PCAs of parts as they are processes via incoming QA inspection procedures.
- Parts are checked against the Indentured Parts List (IPL) prior to integration into their next higher assembly.
- A program management level review of the configuration history of all major components is held prior to shipment of the vehicle to the field site.

The Configuration Administrator provides assistance and information to the QA engineer and the program office during these incremental PCAs.

The Functional Configuration Audit (FCA) is the comparison of actual performance test results to the specification requirements. The as-designed component configuration is reviewed against the specification or requirement documentation by the principal systems engineer during the design phase. The QA engineer reviews test results and documentation and insures the results meet specification requirements. The Configuration Administrator provides assistance and information to the appropriate systems engineer during these incremental FCAs. Any discrepancy identified during these audits is documented on an NCR.

QA inspects all flight hardware. Only the non-flight items that are required for system testing are inspected and verified by QA, i.e., mass simulators used on the Captive Carry Vehicle. QA inspection for tooling used for fabrication is at the discretion of the cognizant engineer.

Software Control

The X-34 program uses Polymake Version Control System (PVCS), an off-the-shelf CM tool for software configuration control. This tool controls software at the module level as well as the vehicle level. For each module in the X-34 program, an archive is maintained which tracks modifications to the module. Any past revision can be re-created at any time since the revision history and changes are stored by PVCS. The software librarian has privileges to write a new version into the library. All changes are monitored by the X-34 software configuration management officer.

At the vehicle level, a version label is assigned to a set of specific revisions of vehicle software modules. Once a version label is assigned, this set of specific modules may be re-created at any time.

Software modification can be driven by changes to any of the following:

- mission specific or functional requirements (as defined in the Mission Requirements Document)
- system/segment specifications
- problems found in the field or during testing